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ABSTRACT *(MAXIMUM 200 WORDS)*

Considering the capabilities of existing simulators, the training models of the commercial aviation industry and KC-130J community, and available scientific research, creating a MV-22 training model that reduces or eliminates the requirement for a FRS is a realistic goal. In the face of looming budget cuts, the Marine Corps must find efficiencies to reduce costs while preserving current capability. Just in MV-22 flight hour costs alone, capitalizing on existing simulator technologies and proven training models could yield in excess of $200 million in savings over a 10-year period. To achieve this, the Marine Corps must mandate change and leverage the training models of the commercial commercial aviation industry and the KC-130J community.

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MASTER OF MILITARY STUDIES

**The Simulator: A Path to Preserve Capability While Reducing Costs**

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF MILITARY STUDIES

**MAJOR RYAN C. POPE**

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## Executive Summary

**Title:** The Simulator: A Path to Preserve USMC Aviation Capability While Reducing Costs

**Author:** Major Ryan C. Pope, United States Marine Corps

**Thesis:** Success in the commercial aviation industry and the Marine Corps KC-130J program demonstrate that a simulator centric training model minimizes flight hour costs while maintaining aircrew capability. Application of this model to other aircraft in the Marine Corps inventory has the potential to provide cost savings measured in hundreds of millions of dollars without a reduction in aircrew capability.

**Discussion:** The commercial aviation industry, in which financial success is dependent on safety, has wholly embraced a simulator centric training model. Considering the necessary emphasis on safety, and devastating economic impact of an accident, it is noteworthy that civilian airlines and the government allow for all airline flight training to occur in a simulator. Perhaps surprising to some, an airline co-pilot's first flight in a real aircraft has passengers aboard. Unfortunately, it is difficult for Marines to view the commercial aviation industry's training model as applicable. The aircraft are vastly different from those in the military, and the pilots that commercial aviations hire are already experienced pilots.

The USMC KC-130J program provides another, more relevant example of a successful simulator centric training model. Additionally, and unlike other USMC aviation communities, there is not a costly, traditional Fleet Replacement Squadron (FRS) for the KC-130J. The KC-130J training is more applicable than the commercial aviation example because aircrew must conduct missions at low altitude, conduct defensive maneuvers, be qualified on Night Vision Devices (NVDs), and with the addition of the Harvest Hawk, even employ weapon systems. The MV-22, in particular, not only has similar assigned missions as the KC-130J but the two aircraft also share surprisingly similar performance characteristics and employ similar tactics.

In addition to dedicating twenty MV-22s to a training role only, the total annual flight cost for the current MV-22 FRS is $42,199,960. Mandating a formal study of the training effectiveness of existing simulators, coupled with a review of the syllabus, would likely find the simulator well suited to replace additional training sorties. Reducing FRS student flight events by only 50%, from 24 to12, would amount to $21.2 million per year in flight hour savings. Furthermore, a reduction in required flights would negate the requirement to have 20 aircraft at the FRS. Thus, some number of MV-22 aircraft and personnel could then be available for the fleet to employ.

**Conclusion:** Considering the capabilities of existing simulators, the training models of the commercial aviation industry and KC-130J program, and available scientific research, creating a MV-22 training model that reduces or eliminates the requirement for a FRS is a realistic goal. In the face of signifigant budget cuts, the Marine Corps must find efficiencies in order to reduce costs without sacrificing capability. In MV-22 flight hour costs alone, utilizing existing simulator technologies and proven training models could yield in excess of $200 million in savings over a 10-year period. To achieve this, the Marine Corps must mandate change and leverage the training models of the commercial aviation industry and the KC-130J community.

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## Introduction

Flight simulators, in varying forms, have been part of flight training for the majority of aviation history. The ubiquitous Link trainer, which resembled a large toy airplane, characterized World War II pilot training. A relatively simple mechanical device, the Link trainer taught pilots how to use flight instruments and controls.[1] Since the Link trainer, advancements in technology have enabled contemporary flight simulators to develop into complex devices that accurately duplicate both the flight environment and the flight characteristics of a specific aircraft.

Excluding the KC-130J program, Marine Corps aviation has not employed simulator technology to its fullest. In the coming years, the Department of Defense faces substantial budget reductions. Flight simulators provide an opportunity to train aircrew without the expense of purchasing and operating dedicated training aircraft. Success in the commercial aviation industry and the Marine Corps KC-130J program demonstrate that a simulator centric training model successfully minimizes flight hour costs while maintaining aircrew capability. Application of this model to other aircraft in the Marine Corps inventory has the potential to provide cost savings measured in hundreds of millions of dollars without a reduction in aircrew capability.

## The Promise of the Simulator

Over the last several decades, the potential cost saving benefit of flight simulators has grown in conjunction with the exponential increase of aircraft operating costs. In 1970, the P-3 Orion, a multi-engine turbo-prop aircraft, had a cost per flight hour of approximately $450 (the equivalent of $2,699 in 2011). That same year, flight simulators had a cost per flight hour of approximately $60 (the equivalent of $356 in 2011).[2] Thus, simulators represented a cost savings of approximately 87%. In 2011, the cost per flight hour for similar aircraft was over $10,000. The cost per hour for flight simulator operation has remained steady at approximately $350 per hour.[3] Thus, in 2011, flight simulators represented a cost savings of nearly 97%. Not only has simulator technology increased greatly since 1970 but also the cost benefit has increased. This has enabled flight simulators to become the cornerstone of commercial aviation training. Nevertheless, Marine Corps aviation has not leveraged flight simulators to a similar advantage.

Different simulators cover the spectrum of training requirements and budgets. Simulator design ranges from simple Flight Training Devices (FTD) to complex Full Flight Simulators (FFS). FTDs are best suited for learning rote tasks and procedures and may range from a personal computer driven flight simulator, which utilizes generic flight controls, to a Cockpit Procedure Trainer (CPT) that provides greater realism for a specific aircraft. A CPT is a full cockpit that represents a specific aircraft but usually lacks an accurate flight model and out-of-the-window displays. Civilian flight schools commonly employ the less expensive personal computer driven devices, while the military commonly employs the more complex and expensive CPTs.

Full Flight Simulators, at varying levels of Federal Aviation Administration (FAA) qualification, accurately represent the cockpit, noise, and flight characteristics of the simulated aircraft, as well as provide physical motion and display realistic scenes. The FAA allows for the completion of all Commercial aviation Transport Pilot (ATP) training in a Level D simulator.[4] By this FAA standard, flight time in a Level D simulator is equivalent to real flight time.

In addition to providing safe and effective training at a reduced cost, the use of Full Flight Simulators (hereafter simulators) reduces risk to precious aircraft and aircrew. The increased cost of modern aircraft has led to a reduction in the total numbers of aircraft purchased by the military. Not only are there less aircraft available, but also they must provide decades of service. The trend of increased cost and reduced numbers of aircraft makes training losses of aircraft unsustainable and the non-essential use of the airframes irrational. Simulators allow an organization to avoid the unnecessary aircraft usage for training.

Simulators also have the capability, in many regards, to offer superior and more realistic training. Rarely are aircraft engines shut down for training purposes. Rather, the employment of an idle power setting provides the only means to replicate a failure. Operating an engine at idle power and calling it a failure presents an undesirable training condition. First, at idle power turbine engines still produce thrust. This gives the aircraft different flight characteristics than if the engine was inoperable. Second, with the reduced power available, even an experienced pilot my inadvertently place the aircraft into an unsafe flight regime. Lastly, from a procedural standpoint, the pilot in an actual aircraft is unable to manipulate the required switches, levers, or buttons in accordance with the proper procedure for an engine failure. Instead, the pilot in the actual aircraft must simply touch or point at controls, or risk actually shutting down the engine. Training in that manner may foster inappropriate techniques and ultimately result in negative learning. In the simulator, a pilot can fully experience the realistic flight characteristics of an engine failure and complete all procedures without risk to equipment or personnel.

The commercial aviation industry, in which financial success depends on safety, has embraced a simulator centric training model. The industry conducts all training and most pilot evaluations in flight simulators, as it makes little financial sense to utilize aircraft for initial training flights.[5] Utilizing aircraft for initial training would cost thousands of dollars per flight hour, expose the aircraft to unnecessary risk, and produce no revenue.

Considering the necessary emphasis on safety and the huge economic impact of an accident, it is noteworthy that civilian commercial aviation companies and the government allow for all flight training to occur in a simulator. In fact, an airline co-pilot's first flight in a real aircraft has passengers aboard.[6] The obvious implication is that simulators provide a safe and cost effective alternative to training in actual aircraft. While not all civilian training practices are compatible to adaptation by the Marine Corps, an examination of commercial aviation training highlights the cost inefficiency of Marine aviation training.

**Overview of Current USMC Aviation Training**

In contrast to the commercial aviation industry, Marine aviation routinely utilizes aircraft for initial training flights. It continues this practice even though many USMC simulators are equivalent to a FAA Level D qualification.[7] Such training flights cost thousands of dollars per flight hour, expose the aircraft to unnecessary risk, and do not support any assigned missions. In addition, Marine aviation dedicates dozens of aircraft, which may cost in excess of $60 million each, to a training role only.

Currently, all USMC pilots begin their aviation careers with common ground and flight training known as Primary Training. In Primary Training, student pilots learn basic flying and instrument skills with simulators and single engine turbo-prop airplanes. Through a combination of a student aviator's grades, individual choice, and the needs of USMC aviation, student aviators advance to one of four, aircraft-type specific, Intermediate Training programs: rotary-wing, fixed-wing, multi-engine fixed-wing, and tilt-rotor. Those selected for rotary-wing aircraft continue their training in light turbine powered helicopters. Those selected for fixed-wing continue their training in light single engine jets. Those selected for multi-engine continue their training in twin-engine turbo-prop airplanes, and those selected for tilt-rotor continue their training in both light turbine powered helicopters and twin-engine turbo-prop airplanes. Upon completion of Intermediate Training, the student aviators become fully-fledged Naval Aviators and head to a Fleet Replacement Squadron (FRS).[8]

At a FRS, pilots and aircrew learn the specifics of the aircraft and the basic mission skills that they will employ when eventually assigned to a fleet squadron. A FRS is a fully functional squadron, complete with actual Assault Support aircraft and Tactical aircraft.[9] The average FRS squadron consists of several hundred Marines and is comparable to a normal fleet squadron. It will have a similarly sized maintenance department and administrative staff, as well as the appropriate facilities and ground support equipment. The difference is that an FRS is solely committed to training newly minted aircrew and does not support any assigned USMC missions. Dedicating entire squadrons to a training only role is obviously a costly endeavor. It is immediately clear that altering the FRS concept to rely more on simulators has the potential to save hundreds of millions of dollars per year.

**Why Are Simulators Not At The Forefront Of USMC Aviation Training?**

The Marine Corps has, through various means, attempted to increase simulator utilization to some degree of success. The governing document for USMC aviation training, the Aviation Training and Readiness Program Manual, states that all aircrew shall complete a quarterly emergency procedures review in a simulator and that “to the maximum extent possible, annual instrument evaluations shall be completed in the simulator.” It also states that the Training and Readiness manuals for specific aircraft “shall maximize the use of simulation.”[10] However, the drafting and refinement of an aircraft’s specific Training and Readiness manuals is the responsibility of each aircraft community. Despite the fact that these efforts have generally increased the utilization of simulator assets, there is still an overwhelming belief by many pilots that there is no substitute for the real aircraft.

The most common argument against increased reliance on simulator training is the perception that simulators are not “real” enough. This belief may result from an individual’s own training background, developed by the fact that most training experiences occurred in actual aircraft, or by perceived technological limitations. Nonetheless, the belief that simulators are not “real” enough, in fact, does have some merit worth addressing.

Despite advancements in technology, aircrew can easily distinguish differences between the simulator and the aircraft. One of the most obvious differences is that it is extremely “difficult to simulate the psychological stress that can be caused by anticipation of the catastrophic consequences of serious in-flight errors or lapses in judgment.”[11] Pilots know that they will always walk away from the simulator but recognize that they may not always walk away from an aircraft. No matter how seriously a pilot takes a simulator flight, the mind is conscious of the fact that there is no chance for harm. The simulator pilot will not have to explain why a multi-million dollar aircraft suffered damage due to a hard landing or face the burden of responsibility for the safety and well-being of the dozen Marines riding in the back.

There are also physical limitations that are inherent to simulator devices. Simulators rely on the physical movement of the device, combined with visual cues, to approximate angular accelerations. A simulator’s limited range of motion ensures the physical sensation of pulling “g’s,” the gravitational forces resulting from sustained accelerations, is impossible to replicate. Upon initiating a turn, the simulator device will roll in the direction of the turn to stimulate the semicircular canals in the inner ear and simultaneously pitch up to provide the sensation of angular acceleration or g-force. This initially results in a believable sensation of physically entering a turn, but because the simulator has a limited range of motion it can only present this sensation for a short duration. Thus, a pilot in a simulator does not experience the physical and sensory stress that would normally be present during aircraft maneuvers.[12]

Despite technological advances, there are also inherent limitations to visual displays that will never allow a simulator to be truly life like. The physical video displays used to present the visual scene surround the windows of the simulator cockpit to provide a normal field of view. Most current USMC simulators have a field of view that provides at least 180 degrees of horizontal field of view. Of note, the FAA requires 176 degrees of horizontal field of view as part of the requirements for Level D qualification.[13] Regardless, the field of view in a simulator will rarely provide the same field of view that pilots in a real aircraft rely upon. In an aircraft, the pilot can lean forward or otherwise move his or her head to maintain visual contact on an object of interest. In a simulator, leaning forward or moving the head beyond the normal range of motion will generally result in seeing the edge of the visual display monitor. In a simulator, this often complicates such issues as rendezvousing with another aircraft or visually acquiring terrain and obstacles prior to maneuvering. The video displays also ensure that the vertical field of view in a simulator is much less than in an aircraft. This makes it next to impossible during high angle of bank turns to look up and see into the turn. Again, the pilot of an actual aircraft can usually lean or move his or her head to look and gain adequate visibility into the turn.

Lastly, even the most advanced digital graphics do not provide a truly life like representation. Computer graphics are subject to the limitations of processor speed and the design costs of modeling objects. These limitations usually result in a few, highly detailed objects displayed in a scene characterized by mostly low detailed objects. Even though specific objects on the ground may be of excellent detail, the texture and the contrast of shadows, which characterize terrain at low altitude, are generally missing. This affects the optical flow presented to the pilot and, in certain flight regimes, deprives the simulator pilot of critical and intuitive visual cues regarding speed, altitude, rate of descent, and relative motion.

Based on the inherent limitations of simulators, the conclusion that they are only useful as supplemental training aids and not as a replacement for extensive training in an aircraft appears logical on the surface. Although it may be easy to accept this conclusion, it results from the perception of pilots who have an experience and cultural bias towards training in real aircraft. Furthermore, this conclusion is at odds with research and the successful implementation of simulator centric training models by the commercial aviation industry and the KC-130J program.

While not all commercial aviation-training practices are applicable to the military, it is irresponsible to ignore the successful training concepts of an industry that dwarfs the military. In 2010, the four largest commercial aviation carriers in the United States alone flew 2,959,121 domestic sorties.[14] Assuming a conservative average of 1.5 flight hours per sortie, this equals 4.3 million flight hours in 2010. During that same year, there were also no U.S. commercial aviation fatalities.[15] The Navy and Marine Corps, in comparison flew just 893,477 flight hours, suffering seven non-combat mishaps and multiple deaths.[16] The evidence of the commercial aviation industry's successful training concepts is overwhelming.

**What Is Required In A Simulator?**

To replace real aircraft for initial training, the simulator does not have to present an exact re-creation of the complex physical sensations and sounds that the pilot in a real aircraft experiences. Nor must the virtual world, as viewed by a pilot in a simulator, be indistinguishable from the spectacular views that lay beyond the windscreen in a real aircraft. Nonetheless, these are the measures to which pilots often default when assessing a simulator's fidelity. In truth, a pilot's perception of how realistic a simulator appears is not an accurate measure of a simulator's fidelity.

A better measure of simulator fidelity, and thus training effectiveness, "is the ability of the simulator to elicit pilot or aircrew behavior that is indistinguishable from behavior that occurs in the operational aircraft. This behavior includes not only the manner in which the simulated aircraft is flown, but also the cognitive behavior of the pilot."[17] Thus, if changes in control behaviors are not required to compensate for differences between the simulator and the aircraft, then the simulator is of sufficient fidelity. The subjective measure of realism, applied by the same senior pilots who are responsible for refining the training syllabi, is wholly misleading. Examining USMC simulators from an objective perspective, based solely on training effectiveness, would likely find them well suited to replace training currently conducted in aircraft.

Scientific research clearly identifies a gap between the subjective measure of realism and the objective measure of training effectiveness. A relatively recent study conducted in 2004 suggests simulator motion is not a critical component of transfer of training from the simulator to the aircraft. The study compared pilot control behavior in an actual Cessna Citation, a twin-engine business jet, to behavior observed in a Citation simulator. It was determined that simulator motion "enhanced a pilot's subjective rating of simulator realism, but had no reliable effect on pilot control behavior."[18] These results emphasize the difference between a pilot's perceptions of how realistic a simulator is versus how effective it is at training a desired behavior or skill set.

In response to questions regarding simulator fidelity requirements, the U.S. Army Research Institute (ARI) published a 2008 report based on its own research and a review of existing scientific research. The ARI found the "assumption that more realism equals better training is not supported by empirical evidence. The research on transfer of training from simulator to aircraft has demonstrated that contrary to institutional beliefs, training strategy is more important than fidelity with regard to training effectiveness."[19] In other words, a solid training program enables successful transfer of training to the aircraft, even if the simulator is of low fidelity.

While existing USMC simulators have sufficient fidelity, with few exceptions, to replace the vast majority of initial training in actual aircraft, the previously discussed issue regarding the inherent lack of psychological stress may require some changes. Just because the simulator will always be a virtual world, bolted securely to the ground, does not suggest there are not other means with which to ensure a pilot experiences a sufficient level of psychological stress. Changing the culture within the aviation community is critical to this undertaking.

The training value of flight simulators is greatly dependent upon user motivation. In turn, user motivation is greatly dependent upon the motivation of the instructor. Instructors who believe the simulator is "less than adequate often convey their concerns directly or indirectly to pilot trainees."[20] One method to change this phenomenon is mandating that a simulator flight be treated exactly the same as a real flight. The same level of detailed flight planning, the same level of crew brief, the same personal flight equipment, and the same level of intolerance for negligent errors should be the standard. If an instructor would not fly in the real aircraft with a pilot because there is an apparent lack of preparedness, then the same should be true in the simulator.

There are additional measures, worthy of future examination, to ensure that the psychological stress experienced in a simulator remains commensurate with training requirements. Perhaps, after a pilot reaches a certain level of competency delineated by phase of training, any simulated mishaps a pilot experiences might subject the pilot to some manner of review process. This would serve to reinforce the fact that flying the simulator should have little bearing on a pilot's decision-making and risk assessment process. In order to reinforce further the notion that flying a simulator should not be any different than flying an aircraft, the Navy and Marine Corps should consider allowing specifically delineated simulator sorties to count towards total flight time.

**Example of the USMC KC-130J**

From the perspective of some individuals in the military, applying the lessons of the commercial aviation industry to military aviation training is an "apples to oranges" comparison. The aircraft are vastly different from most military aircraft and the pilots that commercial aviations hire are, in fact, already experienced pilots. Most commercial aviations have a minimum flight hour requirement that is required before even beginning the hiring process. This minimum flight hour requirements for application generally range from 1500 to 2000 hours of total flight time.[21] In comparison, a newly winged Naval Aviator reporting for assignment to an FRS will only have approximately 200 hours of total flight time. With this in mind, suggesting that pilots complete all of their training via simulator seems like a leap of faith for the new military pilot, but not so much for the new commercial aviation pilot.

Those who believe that commercial aviation training is not applicable, also suggest that the mission that commercial aviation pilots must train for is less complex than that of the military pilot. The commercial aviation pilot will fly similar routes to the same airfields and will spend the vast majority of the time at high altitudes. In short, and at risk of oversimplification, training for the commercial aviation pilot must allow him or her to fly from point A to point B safely.

Training for the military pilot must allow safe transit from point A to point B, but also to fly at low altitude, employ weapon systems, conduct defensive maneuvers, and employ night vision devices (NVD) while maintaining situational awareness in chaotic environments.

Fortunately, and in addition to the model of the commercial aviation industry, there is another example of a successful simulator centric training model found in the USMC KC-130J program. The KC-130J training model is more applicable to other USMC aviation programs than the commercial aviation industry is. The pilots that complete the training have the same level of experience as all other new Naval Aviators. The missions that the KC-130J flies are diverse and similar to the missions conducted by other USMC Assault Support aircraft. Aircrew must conduct missions at low altitude, conduct defensive maneuvers, and employ NVDs. With the addition of Harvest Hawk, a precision weapons and surveillance kit, KC-130 crews now even employ weapon systems. The MV-22, in particular, not only has similar assigned missions as the KC-130J but the two aircraft also share surprisingly similar performance characteristics as well as employ similar tactics. Additionally, both aircraft share similar aircrew operating concepts consisting of two pilots and two to three enlisted aircrew.

The current KC-130J training model began in 2002. During that year, the Marine Air Board, a body of key leaders, approved the deactivation of the legacy KC-130 FRS, known as VMGRT-253, by October of 2006. Presumably, due in part to the high cost of the new KC-130J, there were only to be enough airplanes purchased to replace all of the legacy aircraft in the active duty fleet squadrons. This left the Marines with no supportable means to train initial aircrew. The U.S. Air Force was also transitioning to the C-130J, and an obvious solution to the issue was to send USMC pilots through the Air Force syllabus at Little Rock Air Force Base.[22]

The Marines would only complete eight weeks of the USAF training and would require additional follow-up training in order to become qualified. This extra training burden, formerly belonging to the FRS, was now the responsibility of the fleet squadrons.[23] For a few years, USMC pilots attended training at Little Rock, but the arrangement was generally unsatisfactory for several reasons. First, USMC and USAF procedures were vastly different, which required USMC pilots to unlearn much of the USAF training upon arriving at a fleet squadron. Second, the training that was available for the Marine Corps to participate in was too narrow in scope, and the resultant training burden on the fleet was undesirable. Finally, the Marine Corps often lost training slots because, unsurprisingly, the priority for the USAF school went to USAF personnel.

From 2003 to 2006, the USMC conducted its own simulator conversion training to make up for the lack of throughput from the USAF school. Concurrently, civilian consultants refined the Marine Corps KC-130J training syllabus using the Systems Approach to Training methodology. The results of this effort led to the current simulator centric training model for the KC-130J program.

In 2007, the USMC activated the KC-130J Auxiliary Training Unit (ATU) at MCAS Cherry Point, North Carolina. The ATU consisted of one, Level D quality, KC-130J simulator and a handful of civilian instructors overseen by active duty personnel. Later it would encompass another KC-130J simulator located at MCAS Miramar, California. That same year, the USMC opted not to send any pilots to train at Little Rock.[24] By 2008, the Marine Air Board decided to disengage from Air Force pilot training contracts as a Systems Approach to Training had produced a simulator only curriculum for KC-130J pilot training. From the USMC viewpoint, the ATU training was more efficient and more effective than the USAF syllabus.[25]

This change apparently occurred without formal studies to determine the extent to which a simulator could replace training in an actual KC-130. Arguably, several years of continual refinement combined with a lack of alternatives built confidence in the KC-130 community that the simulator could fulfill the majority of initial pilot training requirements. The culture of the community changed from one of a dismissive attitude towards simulator training, to one of treating the simulator like an aircraft. Ultimately, and despite the absence of a FRS for the KC-130 community, the current simulator centric training model has provided an excellent product for the fleet at minimal cost.

Before further discussing specifics of training, a brief overview of training terminology is required. Aircraft specific Training and Readiness manuals, as governed by the previously mentioned Aviation Training and Readiness Program Manual, are broken down by phases of training. There are six phases denoted in a series of events that begins with 1000 and ends at 6000. The 1000 phase denotes Core Skill Introduction training. Core Skill Introduction training is "fundamental training required to fly [or] operate a new type of aircraft [or] system."[26] The 1000 phase is the exclusive purview of a FRS, while the 2000-6000 phases are the responsibility of fleet squadrons.

Per the KC-130J Training and Readiness manual, there are 49 flight and simulator events in the 1000 level phase, which total 174 hours of training. This phase generally takes approximately four months to complete. There are 44 simulator events, totaling 164 hours of training, which have a mean duration of four hours each. The reader should note that 164 simulator hours is a substantial amount compared to other USMC aircraft syllabi. These simulator events introduce a spectrum of missions and skills from normal procedures to NVD sorties and low altitude training. The remaining five events, totaling 10 hours of flight time, are sorties in a KC-130J. They consist of four flights that familiarize the students with the actual aircraft and provide them with confidence in their previous simulator training. The fifth and final flight is a check ride, which qualifies the new pilot as a co-pilot in the aircraft.[27]

While simulator events account for 90% of the initial 1000 phase, the lack of a traditional FRS does create a small training burden on fleet squadrons. An average of 36 initial and conversion pilots complete the syllabus at the ATU and proceed to one of three active-duty KC-130J fleet squadrons (VMGR) per year.[28] The five remaining flights in the 1000 phase total 180 additional sorties that are the responsibility of the VMGR squadrons to complete. This equates to 60 sorties per year, per squadron. In order to support a training model that is absent of an FRS, each VMGR squadron must fly an additional five sorties per month. This additional training burden is relatively minor.

Of note, the ATU, referred to in the singular, actually consists of East and West Coast units. Approximately half of the 36 pilots complete the 1000 phase at MCAS Cherry Point, while the other half complete the 1000 phase at MCAS Miramar. Each ATU location has one full motion simulator, which is time shared with adjacent VMGR squadrons at both locations. This makes a student to simulator ratio of 18:1.

**MV-22 Training Comparison**

As previously mentioned, the MV-22 and KC-130J share similarities that make them well suited for a comparison of training practices. The MV-22 Training and Readiness Manual and the KC-130J Training and Readiness Manual require the completion of many similar skills and missions. The MV-22 training, however, relies heavily on an actual aircraft to complete the 1000 phase of training.

Per the MV-22 Training and Readiness Manual, the 1000 phase consists of 59 flight and simulator events totaling 106 hours of training. There are more total events in the MV-22 syllabus than in the KC-130J syllabus, but the cumulative training total is 68 hours less. Comparable to KC-130J training, this phase takes approximately four months to complete. The 35 simulator events, totaling 68 hours of training, have a mean duration of two hours each. In contrast to the KC-130J syllabus, there are 24 flight events, totaling 38 hours of flight time.[29] In all, simulator events only account for 60% of the MV-22 1000 phase. See Table 1.

**Table 1:**

| KC-130 and MV-22 1000 Phase Comparison | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Simulator Events | Simulator Hours | Flight Events | Flight hours | Total Simulator & Flight Events | Total training hours | % of events in Simulator | Duration |
| **KC-130** | 44 | 164 | 5 | 10 | 49 | 174 | 90% | 4 months |
| **MV-22** | 35 | 68 | 24 | 38 | 59 | 106 | 60% | 4 months |

Unlike the ATU of the KC-130J community, the MV-22 community maintains a traditional fleet replacement squadron, VMMT-204, that supports all 1000 phase training requirements and sends fully qualified co-pilots to the fleet squadrons. Thus, there is no additional training burden on MV-22 fleet squadrons.

The price of conducting all MV-22 1000 phase training within the FRS is extraordinarily high. VMMT-204 has 20 MV-22s permanently assigned.[30] At a 2009 procurement cost of $93 million each, the Marine Corps has devoted $1.9 billion worth of assets that will not support any assigned mission of the Marine Corps.[31] In fiscal year (FY) 2011, the estimated per flight hour cost of the MV-22 was $10,122.[32] VMMT-204 has a throughput of approximately 110 pilots per year.[33] Considering the number of flight hours required by the Training and Readiness Manual, each pilot costs $383,636 in flight hour expenses alone. The total yearly flight cost for 110 pilots is $42,199,960. In order to put $42.2 million in perspective, the total MV-22 flight hour budget for FY2013 is $339.1 million.[34] Assuming 1.2% inflation for the F2011 MV-22 cost per flight hour data, initial pilot training absorbs 12.6% of the entire MV-22 flight hour budget.

There are currently three full motion simulators at MCAS New River, which support both VMMT-204 and adjacent fleet squadrons.[35] These very capable simulators have a 60-by-220-degree field of view, NVD compatibility, aircraft survivability equipment (ASE), forward-looking infrared (FLIR) simulation capabilities, and an accurate flight model.[36] These simulators also meet or exceed the requirements of a FAA Level D qualification.[37] Considering the capabilities of the MV-22 simulators, the training model of the commercial aviation industry, the training model of the USMC KC-130J community, and the available scientific research, creating a MV-22 training model that reduces or eliminates the requirement for a traditional FRS is a realistic objective. Such a change has the potential to yield huge savings to the Marine Corps while preserving existing capability. Furthermore, the concept is applicable to other platforms besides the MV-22.

**Recommendations**

There are several methods with which to increase the utilization of the simulator. One simple method is to mandate a specifically allowed total number of flights for training. The Commandant of the Marine Corps, through the Training and Readiness Manual, could mandate that the MV-22 1000 phase of training, for instance, contain no more than 10 actual aircraft flights. While this method would substantially reduce costs, it is ultimately arbitrary and may adversely affect capability.

An alternate method involves the commissioning of a study to formally establish what training is only suited for the real aircraft or conversely what training is not suited for existing simulators. This study should also review the MV-22 training process to identify the specific tasks actually performed by a MV-22 co-pilot in the fleet and determine which of these tasks require inclusion in the 1000 phase. The review would help ensure that the 1000 phase syllabus consists of “those tasks that are most critical to successful job performance.”[38]

Once this review is complete, the bulk of the study would then consist of an evaluation of simulator transfer of training effectiveness on a statistically significant population of initial accession pilots. This evaluation of transfer of training would objectively compare the average performance of a simulator-only trained group of pilots, by specific skills, against the average performance of a control group completing the existing syllabus.

While suggesting which specific flight sorties are suitable by replacement with a simulator is beyond the purview of this document, it is without a doubt that such a study would provide evidence confirming that many of the 1000 phase aircraft sorties are unnecessary with additional simulator training. The skill known as Confined Area Landings (CAL) currently consists of three simulator events and four flights in the 1000 phase. However, in the 2000 phase at a fleet squadron, a co-pilot will complete an additional seven simulator events and nine flights with a qualified instructor before ever conducting that skill as the aircraft commander. This suggests that such a robust number of actual flight events in the 1000 phase is not truly required.

The cost benefits of mandating change are noteworthy. Even reducing the flight events in the 1000 phase by only 50%, going from 24 to12, would amount to $21.2 million per year in flight hour savings. In order to keep the 1000 phase training duration at the current standard of four months, at least two additional full motion flight simulators are required to lower the student to simulator ratio. Five MV-22 simulators would lower the ratio to 22:1, bringing it close to the KC-130J ratio of 18:1. These simulators cost approximately $11 million each and would mostly pay for themselves in one year of reduced flight hour costs.[39] Considering a simulator per hour operating cost of approximately $350, the increased use of the simulators would amount to $731,500 per year.[40] In all, a 1000 phase MV-22 syllabus with only 12 flights and including the purchase of two new full motion simulators would yield over $182.2 million dollars in savings over a 10-year period. In addition to the flight hour savings, a reduction in required flights would likely negate the requirement to have 20 aircraft at the FRS. Thus, a number of MV-22 aircraft and squadron personnel could then be available for the fleet to employ.

If, as in the KC-130J syllabus, all the events except for five flights occurred in the simulator, it is conceivable that there would not be a requirement for a traditional FRS at all. The remaining five sorties per student would become the responsibility of the fleet squadrons with a total flight hour cost of a mere $8.4 million dollars per year for 1000 phase training. The five, or even slightly more, sorties could consist of familiarization flights, review of critical skills, instrument approaches, and a check ride. Considering there are 11 MV-22 fleet squadrons (VMM), each MV-22 squadron would have to fly 50 additional sorties per year. This equates to a relatively minor burden of just slightly more than four additional sorties per month, per squadron, to support the 1000 phase training.

This method, one without an MV-22 FRS and with a number of sorties absorbed by fleet squadrons, would require additional expenditures for the training of enlisted aircrew. Currently enlisted aircrew training occurs at the FRS and in-conjunction with pilot training. There is no cost data available for estimates of the simulators and equipment that would be required to train MV-22 enlisted aircrew without aircraft. However, the KC-130J community provides an example here as well. Recently, the USMC allocated $100 million to create full fuselage trainers, a cockpit procedure trainer, and networked observer stations in order to train KC-130J enlisted aircrew at two locations.[41] Assuming a similar cost of $100 million for MV-22 enlisted aircrew training systems, the cost savings over a 10-year period would still amount to $202.5 million. This figure does not include the even greater savings that would result from closing the FRS. Furthermore, closing the FRS squadron would support the 2010 Force Structure Review Group's (FSRG) recommendations of reducing "flying squadrons" from 71 to 61, but would save a deployable fleet squadron instead.[42] Clearly, the USMC should formally examine the applicability of the KC-130J training model. (See Appendix A.)

**Conclusion**

The stress that the current defense budget is facing cannot be understated. The Budget Control Act Amendment, a Congressional debt ceiling deal enacted in August 2011, cuts Department of Defense spending by $489 billion over the next 10 years. Additionally, the military likely faces another $600 billion in defense spending over 10 years if Congress fails to take action to stop a second round of cuts mandated in the August accord.[43] The Marine Corps budget will undoubtedly share its burden of these tremendous reductions in spending.

It is imperative that the Marine Corps immediately begin to find efficiencies in order to reduce costs while maintaining current capability to the greatest extent possible. In the MV-22 community alone, further capitalizing on existing simulator technologies and proven training models could yield well in excess of $200 million in savings over a 10-year period. Applying the same training construct to other communities would yield additional cost savings measured in hundreds of millions of dollars. Critically, these savings could come with no loss in existing capability.

To realize these substantial cost savings, the Marine Corps must leverage the training models of both the commercial aviation industry and the Marine Corps KC-130J community.

These models prove that a simulator centric training model successfully minimizes flight hour costs while maximizing aircrew capability. Finally, a mandated change is required. Otherwise, institutional reluctance and existing pilot culture will ensure the slow migration to a simulator centric training will needlessly persist for decades more.

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**Appendix A: Explanation of Calculations**

**Table 2.**

| | |
|---|---|
| **Current Annual Flight Hour Costs** | |
| $10,122 | MV-22 Cost per flight hour |
| x38 | Hours in current 1000 phase |
| $384, 636 | Cost per student |
| x110 | Total students per year |
| **$42,309,960** | Annual 1000 phase flight hour costs |
| **Savings by 50% Reduction in Flights** | |
| $21,154,980 | Annual 1000 phase flight hour costs / 2 |
| x10 | Ten year period |
| $211,549,800 | Ten year savings (flight hour costs) |
| -$22,000,000 | Purchase of two new simulators |
| -$7,315,000 | Increased sim time over 10 years (($350x19hrs)x110studs)x10yrs |
| **$182, 234,800** | Total ten year savings |
| **Savings with Only 5 flights** | |
| $42,309,960 | Annual 1000 phase flight hour costs |
| -$8,350,650 | 5 Sorties @1.5 hrs (10,122x7.5)x110studs |
| -$1,193,500 | Increased sim time (($350x31hrs)x110studs |
| $32,765,810 | Annual flight hour savings w/5 flights |
| x10 | Ten year period |
| $327,658,100 | Annual flight hour savings w/5 flights over 10 years |
| -22,000,000 | Purchase of two new simulators |
| -100,000,000 | Purchase of enlisted aircrew training systems |
| **$205,658,100** | Total ten year savings |

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